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Original Research Article

An Insight Into Veterinary Students' Perceptions on the use of 3D-Printed Bone Biomodels in Anatomy Learning

Key words

veterinary anatomy education;
3D printing;
bone biomodel;
student perspective

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Abstract: Today, conventional teaching methods are losing their effectiveness at transferring knowledge and skills, prompting the presentation of alternative strategies that hold more promise. One of the innovative alternative education materials in veterinary anatomy education is the models produced on three-dimensional (3D) printers. The subject of this study is 4 different bone biomodels 3D modeled and printed with reference to cadaver-derived bones. In the study, a total of 298 students were asked to evaluate these biomodels in terms of their similarity to the reference bones. According to the survey, 75.5% of the students stated that their biomodel resembled the reference bones. In addition, 64.8% of these students stated that the use of biomodels can be efficient in learning the skeletal system. These outcomes showed that a sample from each of the 4 main bone types could be replicated on a 3D printer with an acceptable similarity ratio. Based on student opinions about these four different biomodels, we think that 3d printed biomodels deserve to be evaluated as an alternative in anatomy education.

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Introduction

It is commonly admitted that anatomy education is a very significant field in both human and veterinary medicine (1). The main purpose of anatomy education is to provide students with required basic information of the field via effective learning and teaching methods (2). In theoretical and practical anatomy classes, methods such as verbal expression, visual expression (e.g., slide shows, training videos), software containing 3D visuals, virtual reality, and augmented reality, are widely utilized (3-5). Besides the mentioned methods, educational materials such as cadavers are utilized in practical anatomy education to increase the quality of the training. Plaster, clay, or plastic models, and plastinates, which are acquired from cadavers, are also of use (6-8).

While the computer simulations or atlas pictures, which are used in anatomy training, appeal only to the visual attention of the students, plastinates, clay or plastic models, and cadavers attract visual attention and provide a tactile experience. Educational materials, which are procured from cadavers, provide students with the opportunity to know actual anatomical variations as well as get visual and tactile information (9). Besides the ethical concerns, supplying the educational materials from dead organisms is difficult and the amount of the material is generally inadequate. Furthermore, smell, texture, and students' awareness about the fact that the materials are procured from dead organisms, cause a significant degree of motivational decrease in the learning process/success of the students. One of the innovative alternative educational materials in applied anatomy education is the models produced on three-dimensional printers. Three-dimensional printers, which are regarded as future technology, offer various advantages in terms of material production by going beyond conventional manufacturing methods. 3D printing is defined as the physical output of a 3D design. It is considered different from the conventional production methods which are based on cutting, punching, and molding. These models are claimed to become realistic alternatives of educational materials in comparison with the both conventional models and cadavers (10-12).

The use of 3D printers and adaptation of the 3D outputs in anatomy training is an up-to-date and original subject that is still being studied (13-15). In our study, 4 different biomodels were produced based on cadaver-derived bones. The biomodels were presented to the students for review along with the bones. Students were asked to compare the similarity of biomodels with cadaver bones. In this study, it was aimed to investigate the potential of biomodels as an alternative educational tool by using the student's point of view.

Materials and methods

Reference materials of the study were obtained from the bone archive of Sivas Cumhuriyet University, Faculty of Veterinary Medicine, Anatomy Department. All stages of biomodel production of reference bones were carried out in the Biomodel Laboratory of Sivas Cumhuriyet University, Faculty of Veterinary Medicine, Andrology Department. The method of the study includes the stages of preparing reference bones, 3D modeling and processing of data sets, printing the biomodel on a 3D printer, and statistical evaluation of the models.

Preparing samples

For the production of biomodels, equidea humerus was selected as the sample of long bones; equidae ossa coxae was selected as the sample of flat bones; an equidea 3rd phalanx was selected as the sample of short bones; and finally, an equidea 3rd cervical vertebra was selected as sample of irregular bones. Using these cadaver-derived reference bones, 3D bone biomodels were produced through replication.

3D modeling and processing data sets

Optical scanning method was utilized to obtain 3D volumetric data of each selected bone. Upon placing the reference bones on the scanning bench, datasets of 0.5mm precision were obtained from the bones which were 360° scanned continuously via a 3D scanner (Structure Sensor, Occipital Inc, USA). The object file format (.obj) data sets were transferred to the computer. The initial analysis of the data sets was carried out via modeling software (3D Builder, Microsoft Corporation) and unnecessary details were eliminated. Upon completing the initial analysis, the evaluation of the data sets was carried out via the computerized 3D graphics software (ZBrush, Pixologic). Thanks to this software, geometrical deviations, which stem from the 3D scanning process, were controlled. Biomodels were visually compared with reference bones in terms of their similarities/differences. The redundant data points were

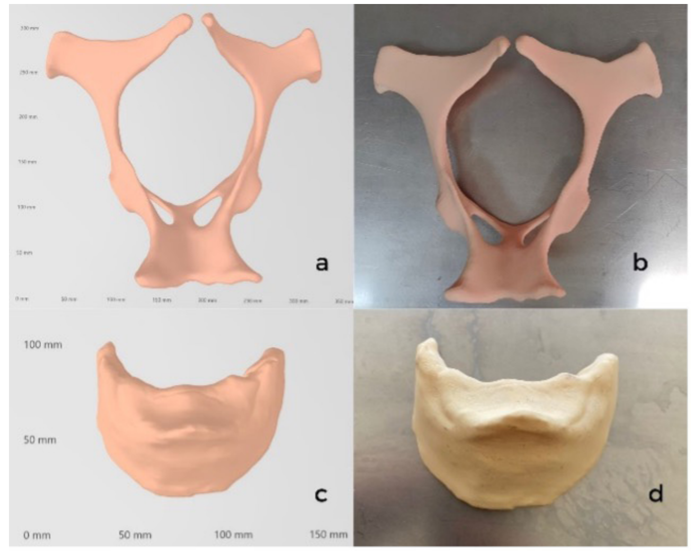

Figure 1: Appearance of specimens with flat and short bones. a; coxae digital model b; coxae biomodel c; 3rd phalanx digital model d; 3rd phalanx biomodel

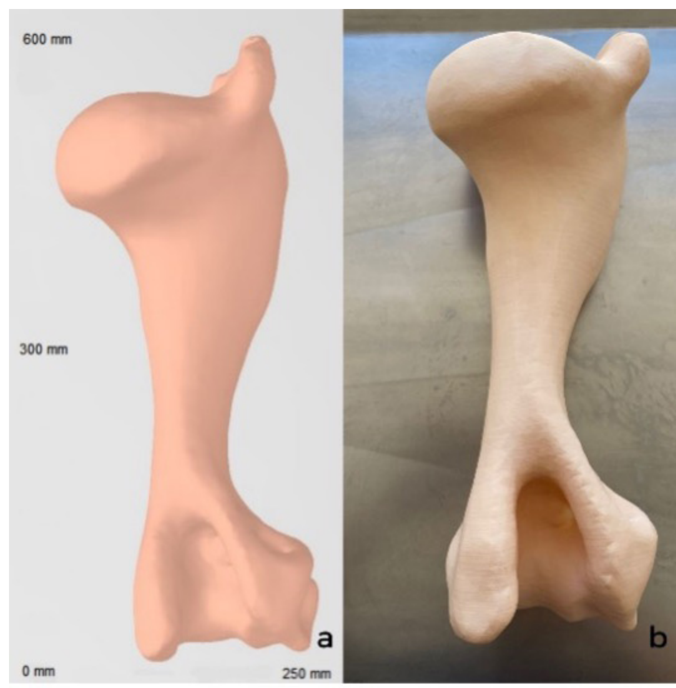

Figure 2: Appearance of specimens with long bones. a; humerus digital model b; humerus biomodel

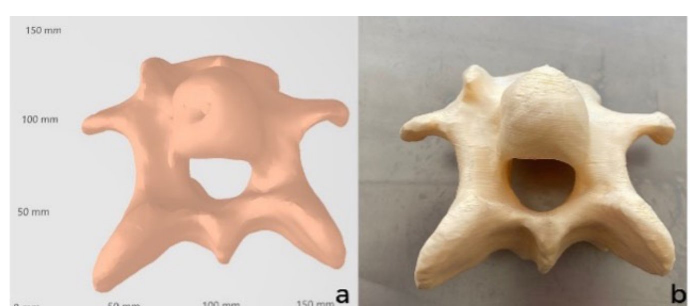

Figure 3: Appearance of specimens with irregular bones. a; 3rd cervical vertebra digital model b; 3rd cervical vertebra biomodel

removed and a single continuous mesh was created. 3D models and reference bones were compared by the anatomist. It was checked whether the 3D printed models had important anatomical features as in the bone from which they were referenced. For the similarity control of the biomodels, 8 criteria for humerus, 7 for coxae, 5 for phalanx and 5 for vertebra were considered. Incomplete-insufficient parts on the 3D models have been edited (e.g. smoothing of facies articularis in the phalanx model). To convert the complete data sets to 3D printing compatible format (gcode). The data sets were transferred to the rendering software (ideaMaker 4.0.1, Raise 3D Technologies, Inc.) of the 3D printer.

3D printing

Rendered data sets were transferred to the 3D printer (Raise 3D N2 Plus, Raise, USA). For the 3D printing process, previously tested and approved poly-lactic acid (PLA) filament (nGen, Colorfabb) was used (Figure 1,2,3). The printing parameters were selected as layer height of 0.28 mm and printing speed of 40 mm/s.

Gathering data

The data of the study was gathered via a quantitative descriptive method. For this purpose, a total of 298 students, who took the Anatomy course of Sivas Cumhuriyet University, Faculty of Veterinary Medicine, were included in the study without sampling. In the faculty where the study was carried out, anatomy course is taught as a total of 12 hours, 4 hours of which is theoretical lectures and 8 hours are practical lectures. While textbooks and atlases are used in the theoretical part of the course, cadavers and plastic models are used in the practical part. The reference bones and biomodels were given to the participants and the participants were asked to examine both groups of materials. Following this step, a Likert scale survey, which measures the attitude of the students towards applied anatomy class and used materials, was filled by the participants (Appendix 1).

Evaluation of the data and statistical analysis

The data obtained from the students were analyzed using SPSS Statistics v.23 for Windows. The students were asked to choose the most suitable one among these options. For the positive items, the options were scored on a Likert-type scale (5 = strongly agree, 4 = agree, 3 = undecided, 2 = disagree, 1 = strongly disagree). When interpreting the arithmetic means, it was considered that the mean values between 1.00 and 1.80 were of value to the extent of strongly disagree, that those between 1.81 and 2.60 were of value to the extent of disagreeing, that those between 2.61 and 3.40 were of value to the extent of undecided, that those between 3.41 and 4.20 were of value to the extent of agree, and that those between 4.21 and 5.00 were of value to the extent of strongly agree. Proportional data were analyzed by using the chi-square test. The method for collecting and evaluating data was designed as double-blind.

Research ethics committee approval

For the study, required approvals were obtained from Sivas Cumhuriyet University Non-Invasive Clinical Research Ethics committee (Res. Number: 2018/10-20)

Results

In the study, a survey was applied to a total of 298 participants, 108 of whom were female and 190 of whom were male. In this survey, the participants' opinions about practical anatomy class, used class materials, and use of biomodels were gathered. When the students' responses for the statements in the attitude scale were evaluated, it became clear that only 21.2% of the participants found the practical anatomy classes adequate (Table 1).

On the other hand, 49.7% of the participants stated that they are disturbed by the smell when they use bones in practical classes (Table 2). In the attitude scale, when the feedback given by the participants to the statements about the use of bio-models is examined, the rate of the participants who find biomodels similar to bones appears to be 75.5% (Table 3).

In addition to these, the rate of the participants who find the use of biomodels beneficial in learning the skeletal system is 64.8% (Table 4).

According to the feedback given for the statement, for which the participants were asked to rate the materials in the applied anatomy classes according to their efficiency levels, it was observed that the most efficient material after the bones is the biomodel (Figure 4).

Table 1: Distribution of the feedback for the statement "Practical classes are adequate"

	n	%
Strongly disagree	42	14.1
Disagree	75	25.2
Partly agree	118	39.6
Agree	53	17.8
Strongly agree	10	3.4
Total	298	100

Mean: 2.71 , Std. Deviation: 1.02.

Table 2: Distribution of Participants' Feedback for the Statements about Bone Use (%)

Statements	Strongly Disagree	Disagree	Partly Agree	Agree	Strongly Agree	Mean	Std. Deviation
Disturbed by the smell of bone.	11.1	18.1	21.1	26.2	23.5	3.32	1.31
Disturbed by the texture of bone.	24.2	33.2	25.2	9.1	8.4	2.44	1.19
Disturbed by bones' belonging to a dead animal.	45.6	30.2	12.8	6.0	5.4	1.95	1.14

Table 3: Distribution of Participants' Feedback for the Statements about Biomodel Use (%)

Statements	Strongly Disagree	Disagree	Partly Agree	Agree	Strongly Agree	Mean	Std. Deviation
Can distinguish the species on biomodels.	3.4	7.0	23.2	45.3	20.8	3.73	0.97
Biomodels resemble the bones.	3.7	2.3	18.1	46.6	28.9	3.94	0.94

Table 4: Distribution of Participants' Feedback to the Statement "Utilizing biomodels in learning skeletal system is efficient"

	n	%
Strongly disagree	21	7,0
Disagree	20	6.7
Partly agree	63	21.1
Agree	89	29.9
Strongly agree	104	34.9
Total	298	100

Mean: 3.79 , Std. Deviation: 1.19.

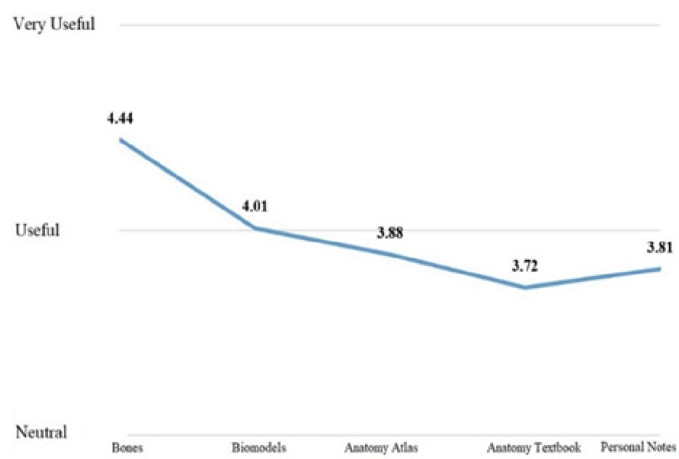

Figure 4: Distribution of the average of utility rating of educational materials according to student attitudes (1: Useless – 5: Very Useful)

Discussion

The success level of veterinarians in their professional life depends on learning skills in many practical fields during their education/training. Anatomy class is the basis of the long training process leading to veterinary medicine (16). In veterinary faculties, students are first faced with the anatomy course. Knowledge of anatomy is acquired with considerable difficulty. In anatomy education, in addition to the quality of the theoretical courses in veterinary faculties, the education standards of practical classes are also tried to be increased and enriched to overcome the educational difficulties (17). The preparation of cadaver poses a variety of challenges, including ethical dilemmas, moral concerns, and complications known as the dissection experience. The development of students clinical skills is directly related to the diversity of the mentioned educational materials. However, obtaining these materials is significantly challenging in financial, ethical, legal, and cultural terms (18, 19). Furthermore, these bones must be processed with a series of chemical solutions to be able to make the bones available for the use of students (20). Formaldehyde and other chemicals, which are the components of these solutions, pose a significant level of threat to the health of both students and trainers (21). Due to the possible hazards of the chemicals which are used in the preparation of practice materials, the use of cadavers is restricted by legal regulations (22). It was determined that only 21.2% of the students find the applied anatomy lessons sufficient in this study when the opinions of the participants to the statements were evaluated on the attitude scale. However, encountering cadavers and bones in the anatomy class causes concerns with the students. Furthermore, this situation leads some students to avoid or to skip practical classes (23, 24). This outcome is not confusing, because the reason for preferring veterinary faculty is undoubtedly the love of animals and the desire to help them for many students.

While anatomy education requires as many samples and varieties of bones as possible, it is also under pressure of perspectives and regulations which prioritize animal welfare. Many anatomy trainers still believe that the ideal form of anatomy education can be provided only through classic cadaver-bone samples which are prepared via methods that have been practiced for longer than a century. However, the search for an alternative method to animal use for educational purposes has become a rising perspective (25, 26). Alternative educational tools such as dummies and models have begun to be utilized in basic classes like Morphology and Andrology (4, 27). Until recently, the inadequate details of these models were a major problem for this field. Biomodels present a novel option for advancing the field of veterinary anatomy education. In this study, the ratio of participants, who perceive the biomodels successful in terms of resembling the reference bones, appears to be 75.5%. In addition, the ability to recognize animal species from bone samples has been demonstrated with high success (79.5%) by the students participating in this study. This showed us that the replication of the reference bones was achieved at a sufficient level. The high-level resemblance of biomodels to reference bones can contribute to the motivation and learning success of students. On the other hand, considering that 49.7% of the participants are disturbed by the smell while using bones in practical classes, the advantage of utilizing biomodel stands out even further. Kucukaslan et. al. reported that the students are particularly hesitant in touching pig, cat, and dog cadavers (28). The fact that the biomodels are similar to the ones and not taken from live animals increases the motivation of students to learn by touching. In another study stated the idea that animal use in biomedical studies is essential (29). This idea is supported by the results of another study, which claims that the most effective learning material is bone. In that study, 28.4% of the participants claimed that personal notes such as sketches are the best learning tools for anatomy class, and 23.7% of them stated that they found the use of textbooks useful, while 14.4% of the participants regarded the anatomy atlas as the best option. Moreover, the ratio of the participants who found plastic models efficient was only 5.4%. In this study, biomodels were interestingly found to be more effective than textbooks and anatomy atlas, and biomodels were stated as the second most useful tool after bone. This outcome stems from the utilization of innovative materials and technologies. Participants adopting such an attitude supports the literature perspective which states that the transfer of knowledge through biomodels will help in clinic practice (1, 17).

Thanks to the 3D printers; production costs will be reduced, and it will be possible to provide each student with an individual biomodel. In addition to the mentioned advantages of biomodels, it must also be remembered that biomodels can also be utilized in other classes such as Pathology, Surgery, Radiology, and Reproduction. However, the utilization of biomodels in anatomy training also has some limitations and disadvantages. The experience gained from dissection practice and necropsy training cannot be substituted adequately by these biomodels (30). The creation of biomodel collections for a variety of animal species within veterinary science will require a significant amount of time. The inability to model small structures (bones of the middle ear) and to maintain color harmony are the main limitations. However, studies on 3D modeling and printing of these structures continue (31). It is predicted that developments will be achieved in this field parallel to the developments in imaging and image processing technologies.

Conclusion

As a result, in our current environment, in which science and technology are developing rapidly, the transfer of knowledge and skills via traditional teaching methods is also losing its validity and plausible alternative strategies are put forward. The use of biomodels should be considered as an alternative that can increase the efficiency of the training process in veterinary medicine. Furthermore, the use of biomodels in practical classes can be of help in relieving the anxiety and discomfort of students.

In this study, it has been shown that biomodel replicas from 4 different cadaver bones can be produced with an innovative method, each with its own anatomical criteria. Moreover, it was concluded that the students deemed these biomodels remarkably alike to their references and approved of their implementation. We think that diversifying education with alternative learning tools will benefit all stakeholders of veterinary medicine, especially students.

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Vpogled v mnenje študentov veterine o uporabi 3D-tiskanih bioloških modelov kosti pri učenju anatomije

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Izvleček: Danes običajne metode poučevanja izgubljajo svojo učinkovitost pri prenosu znanja in spretnosti, zato bi bilo potrebno spodbujati alternativne, bolj obetavne strategije. Eno od inovativnih alternativnih učnih gradiv pri pouku veterinarske anatomije so modeli, izdelani na tridimenzionalnih (3D) tiskalnikih. Predmet te študije so štirje različni biološki modeli kosti, pripravljeni s 3D modeliranjem in tiskanjem, osnovani na kosteh, pridobljenih iz trupel. V študiji je bilo skupaj 298 študentov naprošenih, da ocenijo te biološke modele glede na njihovo podobnost s pravimi kostmi. 75,5 % študentov je navedlo, da je njihov biološki model podoben referenčnim kostem. Poleg tega je 64,8 % teh študentov izjavilo, da je uporaba bioloških modelov lahko učinkovita pri učenju skeletnega sistema. Ti rezultati so pokazali, da je mogoče vsakega od 4 glavnih tipov kosti kopirati na 3D-tiskalniku s sprejemljivim razmerjem podobnosti. Na podlagi mnenj študentov o teh štirih različnih bioloških modelih menimo, da bi 3D-tiskani biološki modeli lahko bili vrednoteni kot alternativni pripomoček pri izobraževalnem procesu anatomije.

Ključne besede: poučevanje anatomije v veterini; 3D tiskanje; biološki model kosti; perspektiva študentov